HEC #2: J³H²R

The University of Texas at TYLER

Electrical & Mechanical Engineering

Hydrocyclone Design

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Sponsor: Stage 3 Separation

Advisor: Dr. Andres Garcia

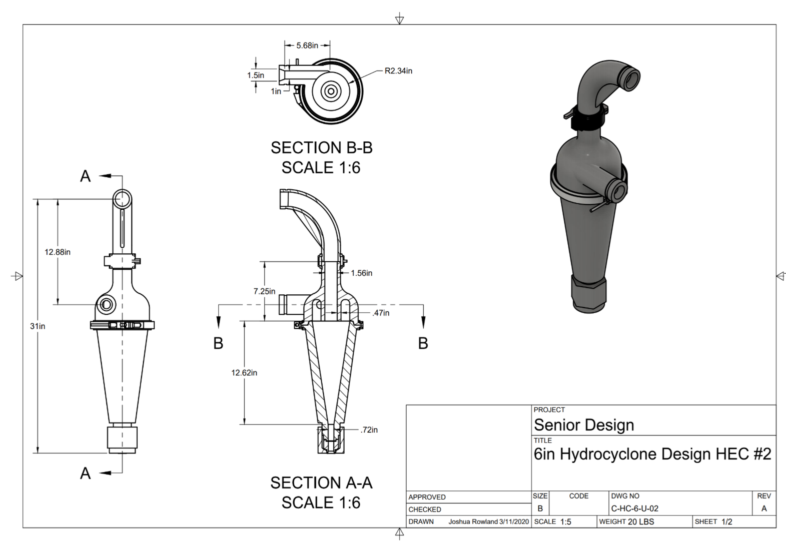
STAGE 3 SEPARATION

J³H²R

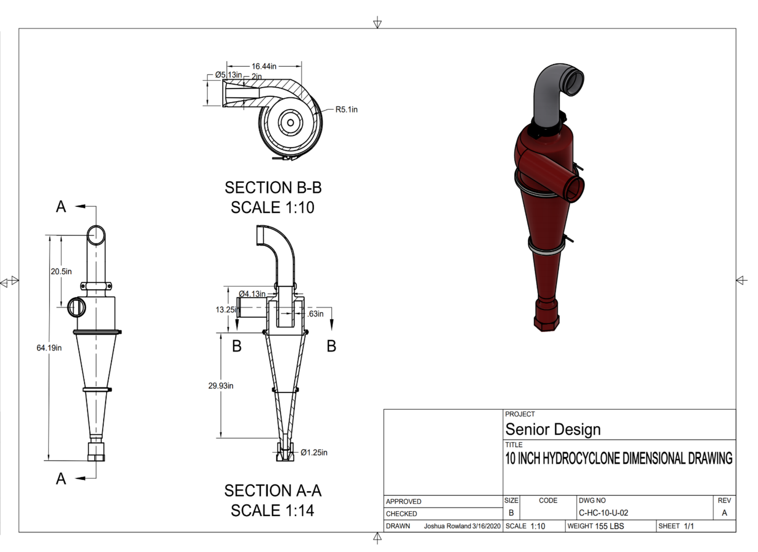
ABSTRACT

- Development of a hydrocyclone fluid/solid separation model was necessary to isolate high gravity solids from oil and gas drilling mud. Since mud parameters of density, viscosity, and fluid/solid concentration vary with each well, a method of predicting geometry of hydrocyclone dimensions was required to produce optimum HGS separation within independent cases.
- A mathematical model consisting of theoretical governing equations was developed to output optimum hydrocyclone geometry or effective cut-point of HGS from inputs of mud properties. Operational hydrocyclone tests and CFO simulations were required to build correction factors for the model and verify effective separation within model simulations.

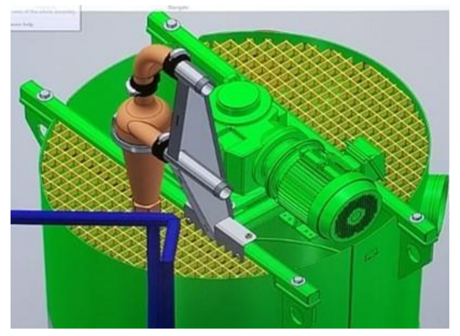
CAD DRAWINGS AND CFD ANALYSIS



CAD Drawing of 6" Hydrocyclone

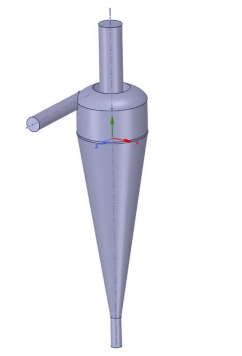


CAD Drawing of 10" Hydrocyclone

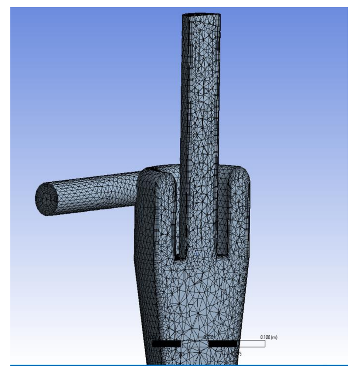


CAD Model of Custom Hydrocyclone Stand

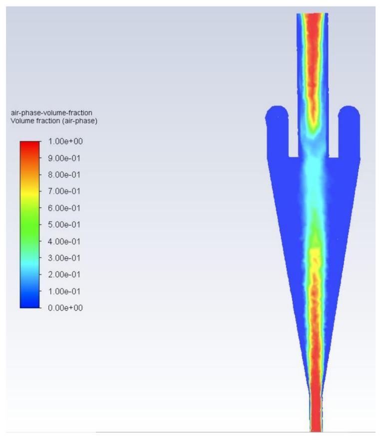
6" Vorspin Hydrocyclone CAD Model



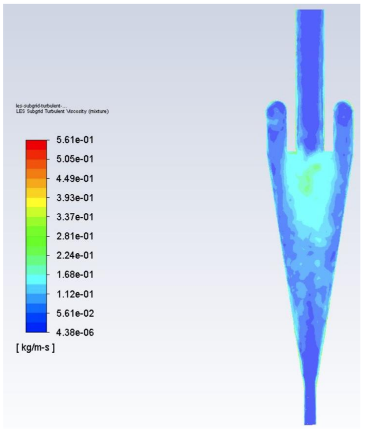
Computational Domain for Hydrocyclone



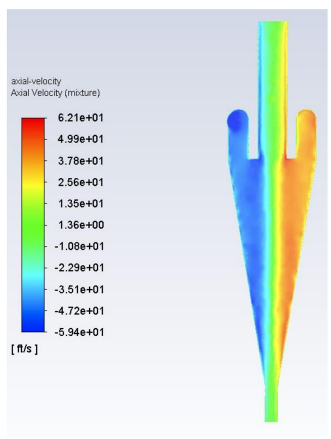
Hydrocyclone Meshing



Air-Phase Volume Fraction (%)



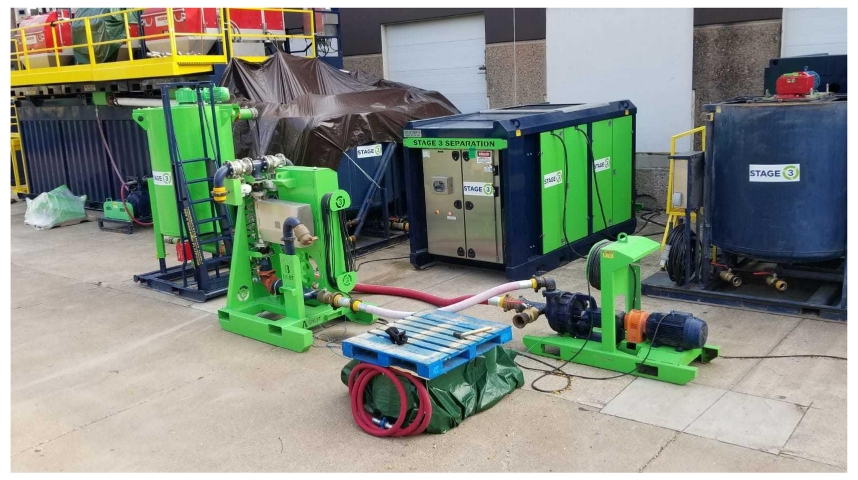
Turbulent Viscosity Contour (kg/m*s)



Axial Velocity (ft/s)

- ANSYS Fluent was used to simulate particulate separation using given flow rates and particle size distributions in order to estimate solid particulate cut sizes
- Fluent calculated the number of particles injected, escaped, trapped, as well as particles that were incomplete due to calculation error caused by skewness of meshing
- Various solid sizes and concentrations were used to simulate realistic scenarios which verified operational testing results

EXPERIMENTAL TESTING



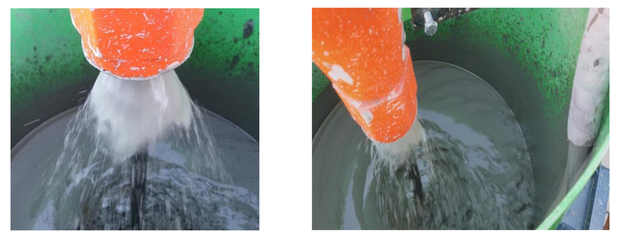
Hydrocyclone Operational Testing Setup

Touch Screen GUI

AC Pump (capacity 1-700 cfs)

Custom 6" Hydrocyclone Stand

Multiple 10" Cones on Mobile Stand (left) and small 2" Cone (right)



Fully Developed (left) vs Weak Cone (right)

Sample Retorts Burned at 925 °F

Build Process of Custom 6" Hydrocyclone Stand

Volumetric Density Scale

Underflow and Overflow Samples

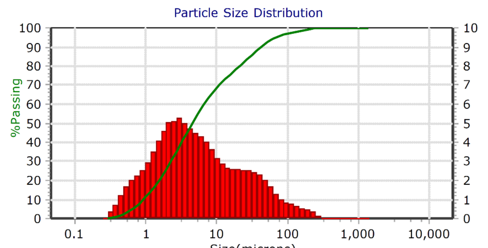
Particle Size Analysis

Crucible Mass

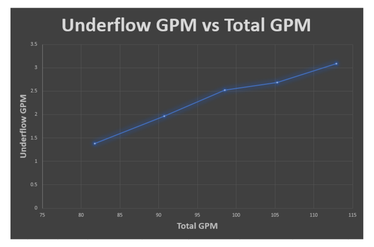
Condenser Mass

Measuring Overflow and Underflow Rates

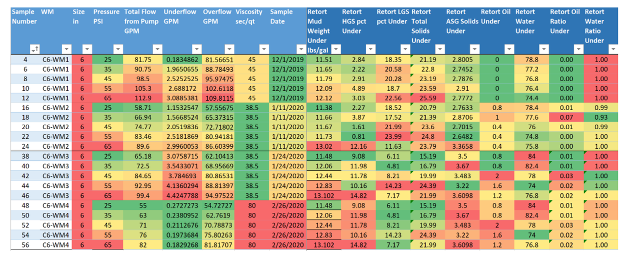
- Drilling mud and high gravity solids were added to the tank
- Initial density, viscosity and mud retort tests were performed.
- The mud was pumped through the hydrocyclone at incremental inlet pressures & samples were obtained from both underflow and overflow outlets.
- Density, viscosity, and retort tests will be performed
- Data collected, sorted and QC'd using Minitab and MS Excel



Particle Size Analysis (micron)



Underflow GPM vs. Total GPM (%)



Regression Equation and Statistical Significance

DESIGN OF EXPERIMENT

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.44689	89.81%	87.78%	84.24%

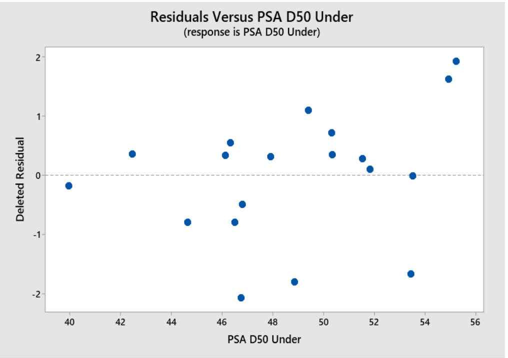
Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	40.74	1.18	34.60	0.000	
Pressure PSI	-2.709	0.341	-7.94	0.000	1.00
Viscosity sec/qt	-6.88	1.22	-5.64	0.000	12.81
Viscosity sec/qt*Viscosity sec/qt	8.49	1.19	7.12	0.000	12.81

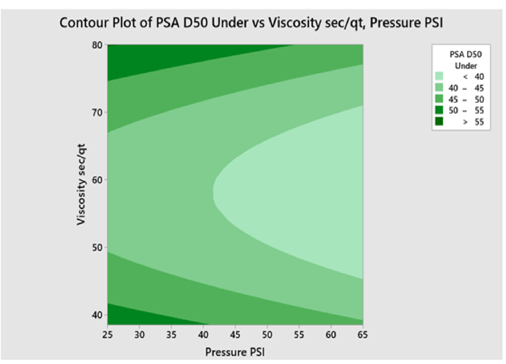
Regression Equation in Uncoded Units

PSA D50 Under = 134.9 - 0.1817 Pressure PSI - 3.007 Viscosity sec/qt + 0.02586 Viscosity sec/qt*Viscosity sec/qt

Regression Equation and Statistical Significance



Residuals vs. D50



Contours of D50 vs. Viscosity

- Minitab General Linear Model derived from 2000+ data points
- Best fit model a function of inlet pressure minus viscosity squared
- P values < 0.001 suggest very strong statistical significance of measured data

FINAL PRODUCT

- Begins with the theoretical governing equations of hydrocyclone liquid/solid separation
- Used to help predict flow fields inside the hydrocyclone that cannot be observed through experimentation
- Refined through iterative experimental testing and CFO
- Unique correction factors apply to varying geometries

	Calculated R Value			Stated R Value		
Dimensions	1D2D	2D2D	1D3D	1D2D	2D2D	1D3D
Hc	1.673	2.136	1.950	1.750	1.750	1.750
Bc	0.837	1.068	0.975	0.875	0.875	0.875
Di (If Circular Entry)	1.335	1.705	1.556	1.396	1.396	1.396
De	2.092	2.136	1.950	2.188	1.750	1.750
Jc	1.673	1.068	0.975	1.750	0.875	0.875
Sc	2.092	0.534	0.488	2.188	0.438	0.438
Lc	3.347	8.546	3.900	3.500	7.000	3.500
Zc	6.694	8.546	11.701	7.000	7.000	10.500

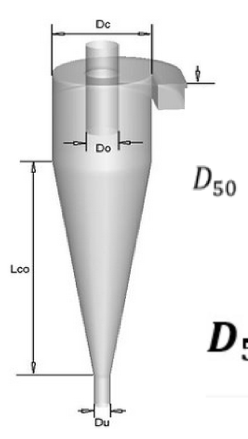
Coefficients	
a	4.75
b	0
d	2.16
f	0.58
g	0.65
h	1
j	1.4
k	0.45
m	0.92
s	-1

Desired Variables	Units	Desired Number
D50	microns	75
Flow Rate	gpm	600
Average SG	Dimensionless	3
Fluid Density	lb/gal	9.15
Funnel Time	sec/qt	45
Solid Concentration	0-100	5
SG Ratio	Dimensionless	2.7361
R Value	in	3.5

Prototype Generation Tables

Independent Variables	Symbol
Interior Body Diameter	D_c
Overflow/Vortex Finder Diameter	D_o
Underflow Diameter	D_u
Inlet Diameter	D_i
Conical Length	L_{co}
Feed Solid Concentration	ϕ
Inlet Velocity	V_i
Relative Density of Feed Material to fluid	P_p
Feed Median Size	$d_{0.5}$
Fluid Density	ρ_f
Fluid Kinematic Viscosity	υ

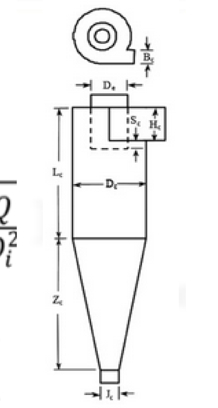
Dependent Variables	Symbol
Cut Size	D_{50}
Pressure Drop	ΔP
Fluid Split	R_f



$$D_{50} = \frac{a D_C^b \frac{D_o}{D_c}^d \emptyset^f \frac{D_i}{D_c}^g \gamma^h}{\frac{D_u}{D_c}^j \frac{L_{co}}{D_c}^k (\varphi_p - 1)^{\frac{m}{\varphi_p}} \frac{4Q}{\pi D_i^2}}$$

$$D_{50} = \frac{\dot{m}_u(d)}{\dot{m}_i(d)} = 0.5$$

D50 Cut Point Equations



Prototype Dimensions

Calculated D50	
1D2D	68.58
2D2D	111.77
1D3D	93.13

Calculated R Value	
1D2D	3.347
2D2D	4.273
1D3D	3.900

Prototype Generation Tables

MATERIAL

CAD Drawings: AUTODESK FUSION 360 CFD Simulations: ANSYS FLUENT Model Interface: Microsoft Excel

Physical Materials and Testing Environments Provided by Stage 3 Separation

CONCLUSION

- Mathematical model will be delivered to the sponsor with an interactive MS Excel interface which requires inputs of mud parameters to obtain accurate hydrocyclone geometry
- Final deliverable will contain the dimensions for a prototype hydrocyclone to fit the sponsor's need
- Long term goals include increasing the number of significant inputs to increase model accuracy, and adding a wider range of mud parameters to increase model domain

ACKNOWLEDGEMENTS

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